AIM

Accelerated Insertion of Materials

DARPA

AFRL

NAWC AD

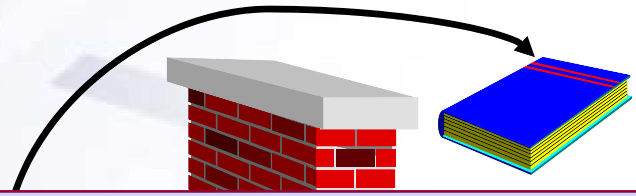
Boeing Aircraft

GEAE

P&W

The Disconnect!

Materials
“Knowledge Base”



Significant disconnect between materials development and the design/use of materials in components /systems

- Known alloy to reliable part - 36 months
- Steels for navy landing gear - 15+ years
- Lightweight composites for army vehicles - 15+ years
- Ceramics for engines - 20+++ years
- Changing ship steels - 7-10 years

Materials Development

- Highly Empirical
- Testing Independent of Use
- Existing Models Unlinked

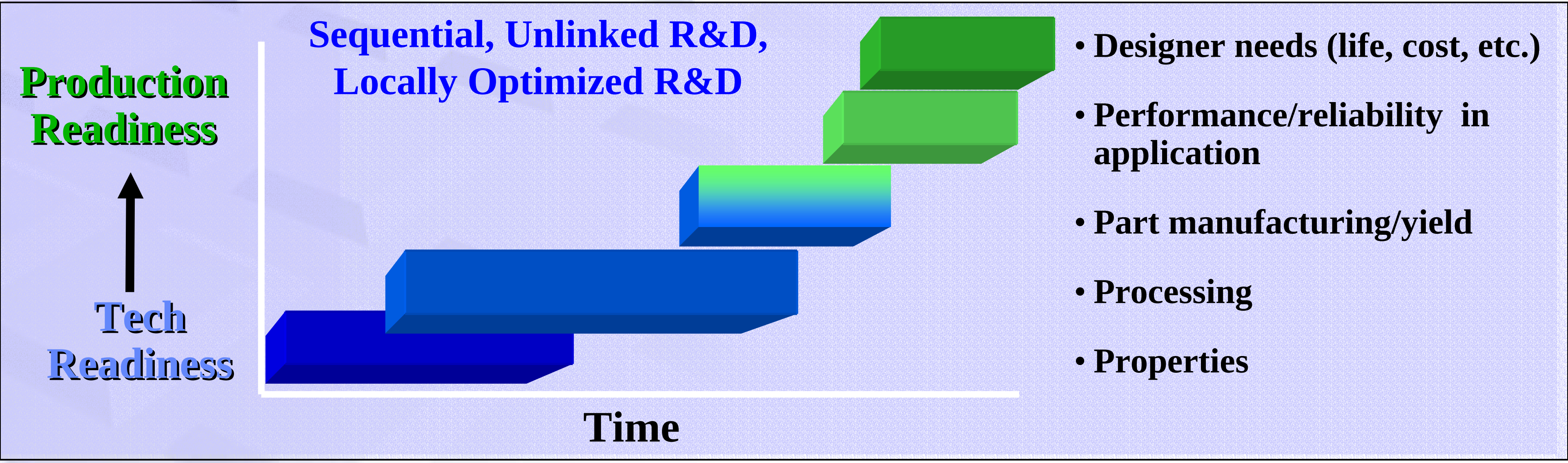
Systems Design

- Materials Input from “Knowledge Base” of Data (Data Sheets, Graphs, Heuristics, Experience, etc.)
- System/Sub-System Design is Heavily Computational and Rapid
  - Clean Sheet of Paper to Engine Design - 30 Months
- Well Established Testing Protocols

The Problem

- Current, empirical approach to materials development is time (& cost) intensive
  - Small, cautious steps in compositional variations, scale-up and processing changes
  - Multiple iterations produce limited (non-statistical) data
  - Early concentration on “primary” properties
  - Does not address designer’s issues and needs
- Real insertion windows often open only for a short time
  - Materials are seldom “production ready”
  - Risk-to-benefit too high
- Outcome
  - Designers choose “known” material -- window closes!
  - Significant impact on performance/cost of past and future defense systems

Current Materials R&D



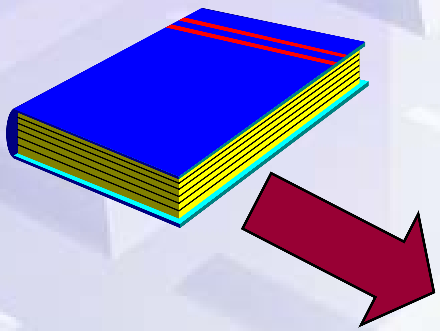
- **Development of properties, processing done without quantifiable link to designer needs**
  - **Optimized properties based on heuristic (gut) feel**
  - **Processing reality requires rework of properties, still no link to designer**
  - **Production readiness steps reworks technology readiness**
    - ***Designer knowledge base NOT ready until final stages***

AIM Goals

Create a new materials development methodology that accelerates the insertion of new materials to achieve parity with the engine /platform development /design cycle

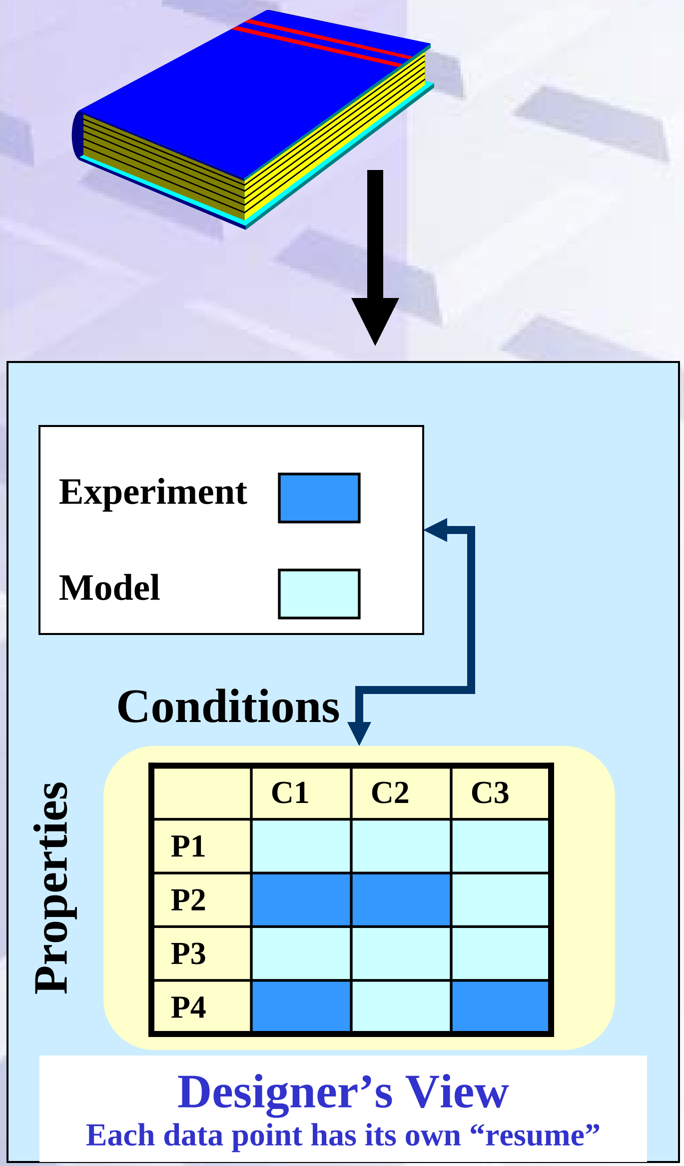
- Tightly couple design and materials activities and tools to establish design-driven material requirements
- Provide designer information earlier with confidence bounds throughout the development cycle
  - *Materials performance, producibility, and cost*
- Reduce insertion risk while decreasing reliance on costly, time consuming data generation
- Create a <u>D</u>esigner <u>K</u>nowledge <u>B</u>ase and tool kit that link with computational design tools

“Knowledge Base” Definition



- Everything designer needs to design a component and decide to use a material
  – Validation of critical properties (with confidence limits)
    - *F (composition, processing, structure, use conditions, ...)*
  – Confidence in scale-up, design and control of process(es)
  – Confidence in manufacture of parts and components (e.g., weldability)
  – Detailed assessment of costs
  – Predictable reliability and life
  – Etc….

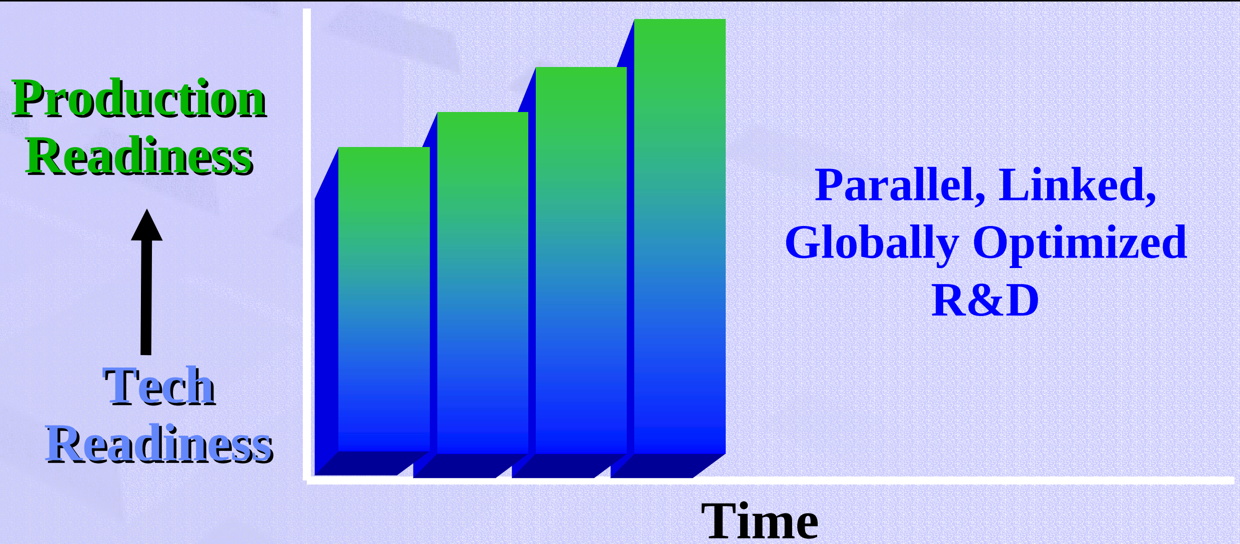
AIM Objectives



Establish a methodology for accelerated insertion of materials into defense structures.

- **Phase I**
  - **Establish a DKB for a currently employed material**
  - **Populate with data from models and/or experiments directed by the new methodology**
  - **Fully integrate into design tools**
  - **Validate against known material database (metals and composites)**
  - **Demonstrate reduction in insertion time**
- **Phase 2**
  - » **Establish a DKB for either a new material or an existing material in a new application.**

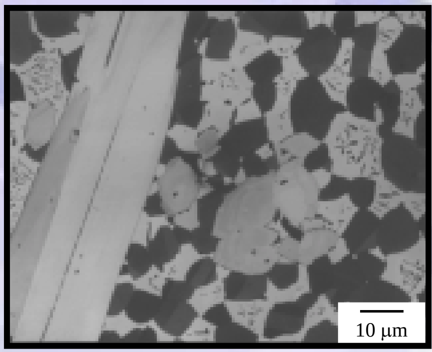
AIM Paradigm in Materials R&D

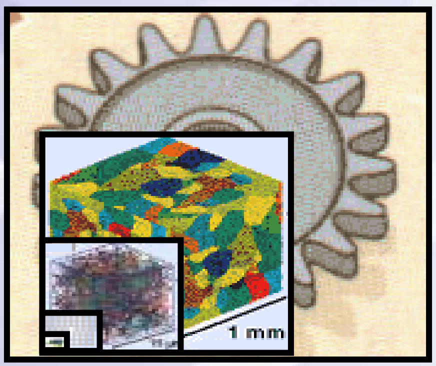


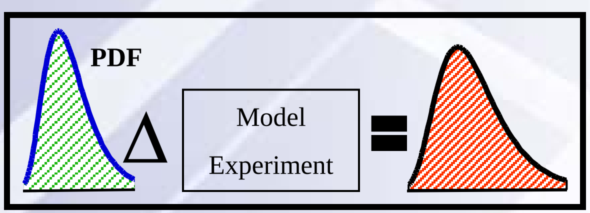
- Designer needs (life, cost, etc.)
- Performance/reliability in application
- Part manufacturing/yield
- Processing
- Properties

- **Development of properties, processing explicitly (through models/experiments) linked to designer**
  - **Development of designer knowledge base begins at outset of R&D**
  - **Optimized properties/processing based on designer need**
  - **Time/effort refines knowledge base**
    - ***Driven by properties, performance, accuracy really needed***

Challenges

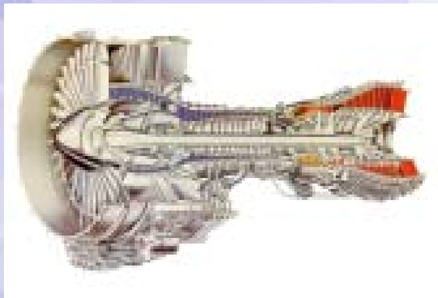






- Knowledge Base Construction
  - Content and Structure
  - Proper Mix of Experiments and Models
  - Knowledge of Uncertainty and Source
- Representation of Materials and Materials Properties
  - Full Composition/Microstructure/ Defects
  - Model Independent, Measurement Independent
  - Amenable to Both Model and Experimental Determination
- Linking of Scales
  - Hierarchical Averaging Principles for Scaling (Without Losing Extremes)
- New, Efficient Experimental Approaches
  - Linked to Models
  - Compatible with Legacy Data
- Propagation of Errors and Variations
  - In Models and Experiments

Progress



- Conceptual
  - Engaged designers
  - Achieved visibility within parent organizations
  - Understood challenge of the program
  - Established aggressive goals
- Technical
  - Established preliminary architecture
    - *DOME*
    - *aimSight/iSight*
  - Identified preliminary and back up models
    - *Phenomenological and data driven models*
    - *Physics-based models for thermal, deformation processing, RTM.*
  - Identified needs for uncertainty and error propagation handling